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ATMOSPHERIC HAZE AND A SUSPECTED VARIATION OF THE SOLAR ROTATION IN 1915

BY H. H. PLASKETT

THIS paper contains a final examination of the evidence presented by Dr. R. E. DeLury in two papers,[1] in support of his theory that blended spectra, produced by atmospheric haze, were the underlying causes of certain solar rotation results obtained by the writer in 1915.[2] The arguments and evidence advanced by him are considered in the first three sections of this paper. In the final section there is a brief discussion of the probable effect of haze on solar rotation displacements.

I. HAZE RECORDS

In Dr. DeLury's first paper the following statement occurred in a discussion of the writer's results:

"The observations were made with the same equipment as I have been using day by day since 1913 for the purpose of investigating any changes which might occur in the positions of lines of limb and centre, so it happened that I made many observations in

[1]Astrophysical Journal, **44**, 198, 1916.
Astrophysical Journal, **48**, 195, 1918.
[2]Astrophysical Journal, **43**, 145, 1916.

various regions of the spectrum during the period of the observations described. The record shows that in general high values of the rotation in the observations mentioned were obtained on brighter days and low values on the hazier days".

The inference to be drawn from the juxtaposition of these two sentences was, that Dr. DeLury had made accurate haze estimates and records by one or other of his well-known methods.[1] Accordingly, in a preliminary note,[2] hastily prepared under the pressure of military duties, the writer endeavoured to show:

(1) That Dr. DeLury had made no such accurate estimates or records of haze.

(2) That even if such a record had existed, it was not applicable to observations made several hours before Dr. DeLury had commenced to observe. Further, and for the same reason, measures of two plates, taken three or four hours later than the writer's, could not be accepted as evidence of the presence of haze during his observations. The only record of haze that was applicable was the rough estimate of brightness made by the writer at the time his plates were taken.

With regard to these two points Dr. DeLury may now be taken to be in substantial agreement with the writer. This is shown in two quotations from his second paper:[3]

"At that time (1915) our records of observing conditions were incomplete in that no account was kept of the strength of the spectrum of haze" (p. 197).

"He should have adopted the logical procedure of juxtaposing his own observations with reference to haze and the respective values of the velocity of rotation" (p. 196. A criticism directed against the writer).

It now becomes necessary to establish a third point with regard to these records of haze. In the course of his second paper, Dr. DeLury makes comparisons between his visual estimates of haze with the corresponding rotation velocities, and the writer's visual estimates of brightness with the corresponding velocities made some hours earlier. From these comparisons he deduces certain results

[1]Ottawa, Report of Chief Astronomer, p. 281, 1911.
[2]Astrophysical Journal, **45**, 144, 1917.
[3]Astrophysical Journal, **48**, 195, 1918.

in favour of his theory. It is therefore advisable to point out, that, while a visual estimate of brightness or haze is self-comparable and self-consistent within certain limits, two such estimates, made by two persons with different mental standards, will be neither comparable nor consistent. This is such an elementary fact of psychology[1] and so much a matter of everyday experience that it needs no emphasis. The æsthetic and moral standards of no two persons are the same. Similarly what the writer considers "bright", no doubt Dr. DeLury would call "hazy". It is clear, then, that results and discussions based on comparisons of two visual estimates of haze by different persons have little weight.

II. Correlation between Rotation Values and the Record of Brightness

Having thus established the common ground that the only haze record, suitable for the purpose and available, is the rough record of brightness made by the writer, it is now possible to examine the correlation between this record and the velocities of rotation. In the writer's earlier paper the following statement occurred: "Plates taken on days hazier than 3.5 were not measured". This is incorrect and should read: "hazier than 3.0." This mistake led the writer to the erroneous conclusion that there was no correlation between brightness and velocity.

The actual facts are given in Table I. In the first four columns of the table will be found the date, the corresponding mean reduced velocity, X, for that date, and the record of brightness, Y, made at the time the plates were taken.

In this record:

5 represents a brilliant day.
4 represents a bright day—no mal conditions.
3 represents a slightly hazy day.

Observations in the record book of the form 3-4, 4-5 are for convenience of correlation called 3.5, 4.5 respectively. The two values 3.8 and 3.2, towards the bottom of the table, are the means of records for those days ranging from 4 to 3.5 and 3.5 to 3 respectively.

[1]W. Glover, "Know Your Own Mind", p. 88. 1918.

In order to determine the amount of correlation between the rotation velocities, X, and the brightness, Y, the usual method,[1] originated by Pearson, was used. The amount of correlation is given by the coefficient r, where

$$r = \frac{p}{\sigma_x \sigma_y} \text{ and } p = \frac{\Sigma(xy)}{N}$$

r can range in value from -1 to $+1$ where 0 represents absence of correlation and unity complete correlation. x, y, are the values of the residuals. (Mean X) $- X$ (Mean Y) $- Y$, and are given in columns 5 and 6 of Table I. The products xy are given in columns 9 and 10 and their sum Σxy at the bottom of the table. σ_x, σ_y are the standard deviations of X and Y, and are determined from the squares of the residuals in columns 7 and 8. N is the number of pairs dealt with—in this case 24. It is thus seen, that

$$r = \frac{+0{\cdot}0068}{0{\cdot}0537 \times 0{\cdot}46} = +0{\cdot}27$$

TABLE I—CORRELATION BETWEEN VELOCITY AND BRIGHTNESS.

Day of Year 1915 G. M. T. (1)	Day of Month 1915 G. M. T. (2)	X Velocities of Rotn. (3)	Y Brightness (4)	x Mean $X-X$ (5)	y Mean $Y-Y$ (6)	$x^2 \times 10^{-6}$ (7)	$y^2 \times 10-2$ (8)	Products xy Positive (9)	Products xy Negative (10)
	June								
172.02	21.02	1.911	4	−.032	+0.1	1024	1		.0032
174.15	23.15	1.885	4	−.058	+0.1	3364	1		.0058
175.07	24.07	1.846	3.5	−.097	−0.4	9409	16	.0388	
176.06	25.06	1.914	4	−.029	+0.1	841	1		.0029
177.07	26.07	1.866	3.5	−.077	−0.4	5929	16	.0308	
179.06	28.06	1.875	4	−.068	+0.1	4624	1		.0068
	July								
182.05	1.05	1.871	3	−.072	−0.9	5184	81	.0648	
184.97	3.97	1.893	3.5	−.050	−0.4	2500	16	.0200	
190.05	9.05	1.919	5	−.024	+1.1	576	121		.0264
190.97	9.97	2.009	4.5	+.066	+0.6	4356	36	.0396	
192.01	11.01	1.975	4	+.032	+0.1	1024	1	.0032	
193.00	12.00	2.000	3.5	+.057	−0.4	3249	16		.0228
201.00*	20.00	2.026	4	+.083	+0.1	6889	1	.0083	
201.99	20.99	1.943	4.5	±.000	+0.6	0	36		
204.05	23.05	2.003	4.5	+.060	+0.6	3600	36	.0360	
205.05	24.05	1.951	3.5	+.008	−0.4	64	16		.0032
207.99	26.99	1.996	4	+.053	+0.1	2809	1	.0053	
208.98	27.98	1.954	3.5	+.011	−0.4	121	16		.0044
210.02	29.02	1.964	3.8	+.021	−0.1	441	1		.0021
211.01	30.01	1.885	4	−.058	+0.1	3364	1		.0058
	Aug.								
222.10	10.10	1.966	3.2	+.023	−0.7	529	49		.0161
223.16	11.16	2.007	4.5	+.064	+0.6	4096	36	.0384	
226.00	14.10	2.006	3.5	+.063	−0.4	3969	16		.0252
228.14	16.14	1.977	4	+.034	+0.1	1156	1	0034	
	Mean=	1.943	3.9		Sum=	69118	517	+.01636	

*As there is no brightness record for 195th day, it is omitted from table.

[1]G. U. Yule: "Theory of Statistics", Chap. IX, et seq., 1917.
D. A. Brunt: "Combination of Observations," Chap. X, 1917.

There is, therefore, as Dr. DeLury has claimed, a small correlation between the brightness record and the velocity of rotation.

For two reasons, however, the smallness of the coefficient makes the correlation of no significance. In the first place, the estimates of brightness, Y, based on a variable mental standard, are only accurate within certain limits, probably 0.5. As an inspection of the table will show, changes of this amount on days now favorable to the correlation would reverse the sign of the coefficient. In particular such changes applied to four days only would make $r = +0.02$. It is evident, then, that this uncertainty in the brightness record renders the coefficient and hence the correlation valueless.

In the second place, on account of the small number of pairs dealt with ($N = 24$), even if the estimates of brightness were accurate, a correlation coefficient of this size would have no meaning. It is a well-known principle[1] in correlation problems, that, for a number of pairs less than 50, a correlation coefficient less than ± 0.50 has no significance. This principle, the result of experience, has been verified by "Student"[2] as the result of a series of experiments on small samples taken at random from a large mass of uncorrelated material. From these experiments he arrives at a somewhat empirical frequency distribution for r, since theoretically established by R. A. Fisher, (*Biometrika* **10**, 507, 1915), from which it is possible to determine the probability of the occurrence of any value of r for a given sized sample. For a sample of 24 pairs drawn from actually uncorrelated material, it is found that values of $r > \pm 0.50$ will occur once in seventy-three times. In other words a value of $r = \pm 0.50$ is not unlikely in a sample of the size considered. This verifies the principle given above. Similarly, for a sample of 24 pairs, coefficients greater than ± 0.27 will occur once in five times. A correlation coefficient $r = +0.27$ is, therefore, highly likely to occur in a sample of the size considered, though there actually is no correlation between the variables. For these two reasons—the uncertainty in the brightness record and the smallness of the coefficient—it is not unfair to state, that the correlation between brightness and velocity has no significance.

[1] G. U. Yule: "Theory of Statistics", p. 187, 1917.
D. A. Brunt: "Combination of Observations", p. 155, 1917.

[2] Biometrika **6**, 302, 1918.

III. Atmospheric Haze and Its Effect on Strong Lines

As the result of a series of measures[1] of blends of the spectrum of the sun's centre in varying proportions on the spectrum of the limb, Dr. DeLury came to the conclusion that strong lines are less affected by such blends than weak lines. On the assumption that a blend of limb and centre is equivalent to a blend of limb and the integrated spectrum produced by haze, he uses this result as a quantitative test for the presence of haze. In both his papers measures of his own plates and of some of the writer's are given which show larger velocities for strong lines than weak. Dr. DeLury therefore concludes, that, on the days in question, the writer's observations were affected by atmospheric haze.

The usefulness of this differential treatment of strong lines as a criterion for the presence of atmospheric haze can best be judged by reference to certain Mt. Wilson observations. In 1914-15,[2] as in 1907-08, observers at Mt. Wilson obtained higher velocities for strong lines. This result Dr. DeLury[3] ascribed on his criterion to the presence of a 9% atmospheric haze during the observations. It has since, however, been conclusively shown (1) by C. E. St. John and W. S. Adams[4] from a test of conditions inferior to those under which their observations were made; and (2) by C. G. Abbot[5] from a discussion of the drift curves made by the spectrobolometer on the days the rotation plates were taken, that *the amount of atmospheric haze present when their plates were taken was less than 1%*.

It is clear, therefore, that in this case the high values for strong lines must be ascribed to some other cause than the presence of atmospheric haze. Consequent upon this failure, Dr. DeLury's criterion, as a test for the presence of atmospheric haze, is no longer of value. This is further confirmed by some as yet unpublished Mt. Wilson measures which show, that even when plates are taken through thick white haze and light cirrus clouds (roughly equivalent to a 10% haze) there is no difference in behaviour of weak

[1] Journal R.A.S.C. **10**, 201, 1916.
[2] Popular Astronomy **23**, 641, 1915.
[3] Journal R.A.S.C. **10**, 345, 1916.
[4] Journal R.A.S.C. **10**, 553, 1916.
[5] Astrophysical Journal, **45**, 65, 1917.

and strong lines. Both suffer about a 5% reduction in velocity, but the ratio of velocities *strong: weak* remains constant.

It may, therefore, be safely concluded, that the presence of higher velocities for strong lines has no significance as a test for the presence of atmospheric haze. The various measures given by Dr. DeLury in his two papers, then, while interesting as indicative probably of certain solar conditions, are not to be regarded as evidence of the presence of haze.

IV. Atmospheric Haze and the Production of Blended Spectra[1]

Atmospheric haze produces an integrated solar spectrum which will be known as the haze spectrum. Accordingly, when the spectrum of the equatorial limb of the sun, for example, is examined on a hazy day each line will be a blend of two lines: (1) the true solar line displaced by rotation and (2) the integrated solar line, corresponding to (1) but undisplaced. The resulting line will then be less displaced than the unblended solar line. According as the haze and limb spectra are combined in different proportions so will the rotation of the sun, determined from line displacements, vary.

It now becomes important to ascertain what function the reduction in velocity is of the atmospheric haze. In an earlier paper[2] Dr. DeLury has given measures of one equatorial plate with superposed haze spectra of different strengths. He finds no reduction in velocity up to and including a 4% haze. An 8% haze reduces his velocity by 5%. In a more recent paper,[3] where blends of limb and centre of sun are measured, Dr. DeLury finds for one equatorial plate (L854), that the equivalent of an 11% haze[4] reduces the equatorial velocity by 5% (p.e. of measurement of unblended spectrum ±.025 km.) For the other equatorial plate (L917) an 11% haze reduces velocity by 11% (p.e. of measurement of unblended spectrum ±.101 km).

In view of the uncertainty of the available experimental data, it becomes important, for the purpose of this paper, to ascertain

[1]Only equatorial velocities will be considered in this section.

[2]Ottawa, Report of Chief Astronomer, p. 281, 1911.

[3]Journal R.A.S.C. **10**, 201, 1916.

[4]R. = 0.89. See original paper.

from theoretical considerations the percentage reduction of an equatorial displacement produced by a given amount of atmospheric haze. Two assumptions will be made:

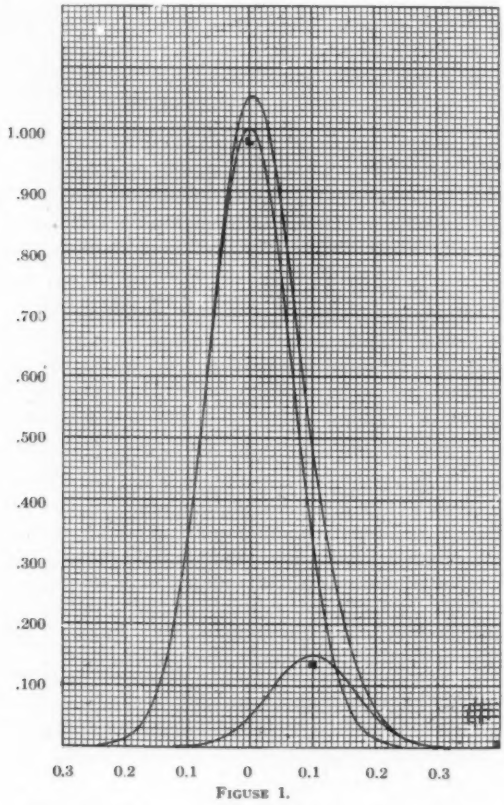


FIGURE 1.

(1) The line is homogeneous, that is, the frequency distribution of intensities can be represented by a function

$$\phi_1(x) = e^{-k^2x^2},$$

where k is a constant involving the width of the line and x is expressed in oscillation frequencies.

(2) The superposed haze line has the same intensity distribution and same width, and can be represented by

$$\phi_2(x) = Ae^{-k^2x^2},$$

where A depends upon the strength of haze and varies from 0 to 1.

The first assumption is justified in the lines usually selected for solar rotation determinations. Such lines are narrow, well defined and without wings under high dispersion. The second assumption represents a close approximation to the truth. The integrated line is similar to a line from the centre of the disc slightly broadened by rotation.[1] Thus the integrated line, or haze line, will be closely similar in breadth and contour to the limb line, which is broader than the same line in the centre of the disc.

Consider a line in the λ5600 region of width $0.1A. = 0.32$ wave numbers (average width corresponding to intensity 3). The distribution of intensities for this line is given by

$$\phi_1(x) = e^{-109\cdot07x^2}.$$

This distribution is shown graphically in Fig. 1 (L). Superpose on this line L a line of intensity $A\,\phi_1(x)$ and displaced by 0.1 wave numbers equivalent to 1.75 km. per sec. This line (H fig. 1 where $A = 0.15$) is equivalent on our second assumption, to the haze line with zero velocity due to a $\frac{100A}{1+A}\%$ haze. The resulting distribution of intensities in the blend is given by

$$\phi(x) = e^{-109.07x^2} + Ae^{-109.07(x-0.1)^2}$$

This is shown graphically in fig. 1. The maximum ordinate, which is the centre of intensity of the blended line, in this graph suffers a reduction in displacement of 0.005 wave numbers. That is, there is a 5% reduction in velocity due to a 13% haze on the assumption, of course, that the centre of intensity is set on in measurement.

More generally, the value of x, for which $\phi(x)$ is a maximum for varying values of A, can be determined from the equation

$$x + A(x-0.1)e^{109\cdot07(0.2x-\cdot01)^2} = 0$$

obtained from $\phi'(x)$. Some numerical values are given in Table 2.

These results are shown graphically in fig. 2 where the strength of haze spectrum in percentage is plotted against the reduction in velocity. It must be remembered that these results only refer to the effect on equatorial velocities. It will be noted that there is,

[1] E. B. Frost: Scheiner's Astronomical Spectroscopy, p. 359.

in view of the variability of the experimental data, a satisfactory agreement between the results of theory and experiment. The unpublished Mt. Wilson result given in the previous section also confirms the theoretical conclusions. Figure 2 may therefore be taken as giving, to a first approximation at least, the percentage reduction in velocity to be expected from a superposed haze spectrum varying in strength from 0 up to 20% of limb spectrum.

It now remains only to determine what the maximum haze was during the time of the writer's observations. Glasses were selected which transmitted less than 1%, 1%, and 5% of light incident on them. It was found in London, on a day with a heavy dust haze, when the sun was casting dull brownish shadows, that the sky just outside the sun's limb was 1% as bright as the sun's centre, that is

TABLE II—REDUCTION IN VELOCITY AS A FUNCTION OF HAZE.

A	% Haze.	× wave numbers.	% Reduction in Vel.
0.000	0.0%	±0.000	0.0%
0.029	2.8	+0.001	1.0
0.059	5.6	0.002	2.0
0.086	7.9	0.003	3.0
0.114	10.2	0.004	4.0
0.140	12.3	0.005	5.0
0.241	19.4%	+0.009	9.0%

2% as bright as the sun's limb.[1] In other words on a day which the writer would not have used for solar observations the haze was 2%. Even when the sun was observed shining through a cloud the equivalent haze was less than 10% of the brightness of the limb.

Making every possible allowance for errors in judgment, it is not unfair to state that the maximum haze possible during the writer's observations in 1915 was less than 5%. Reference to figure 2 will show that this would have produced less than a 2% variation in velocity. To account for the 9% variation actually obtained in velocity would require haze of varying strengths up to 19%, or quite impossible conditions of observation. It may, therefore, be safely concluded that atmospheric haze will only account for a small proportion of the variation obtained.

[1]C. G. Abbot: The Sun, p. 107.

V. Conclusions.

It has been shown in the course of this paper:

(1) That the correlation between the brightness record and solar rotation velocities is numerically too small to be significant.

(2) That the existence of large velocities for strong lines is useless as a quantitative test for the presence of atmospheric haze. Deductions as to the presence of haze from measures showing high velocities for strong lines are therefore valueless.

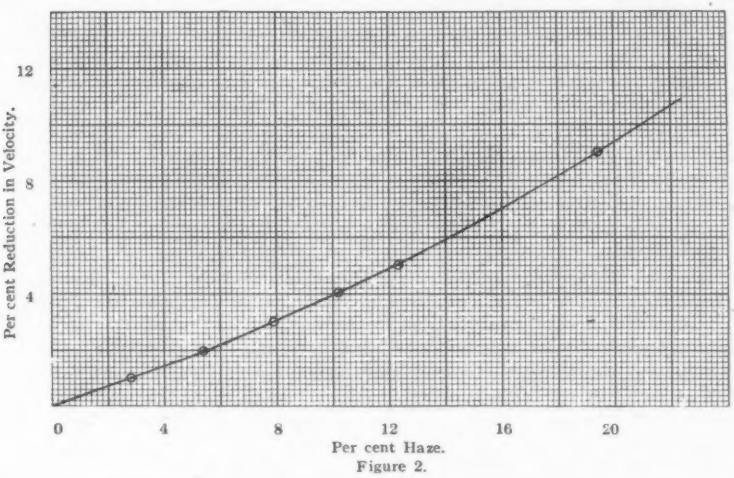


Figure 2.

(3) That the maximum haze to which the rotation observations could have been subjected was less than 5%. This on the basis of elementary theory, the results of which are in fair agreement with experimental data, would account for less than a 2% variation in velocity.

It may, therefore, be safely concluded that some cause or causes, other than atmospheric haze, were responsible for the variations obtained. There are two possibilities. On the one hand the observations may represent an actual variation in velocity in the equatorial belt of the sun. Some weight is lent to this hypothesis from the form C. G. Abbot obtained for his variation of the "solar

constant" in 1915.[1] The similarity between the curves and the coincidences of the minima of the "solar constant" values and the solar rotation values are close. On the other hand, and this in view of recent work at Mt. Wilson[2] seems the more likely, the results obtained in 1915 were simply due to local changes and currents on the sun's surface.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY,
LONDON
May 17, 1919

[1]C. G. Abbot: Periodicity in Solar Variation, Smithsonian Misc. Coll., **69**, 6, 1918.
[2]Publications, A.S.P. **30**, 319, 1918.

ORBIT OF THE SPECTROSCOPIC BINARY 1 GEMINORUM

By Reynold K. Young

1 Geminorum [$\alpha(1900) = 5h\ 58.0m$, $\delta + 23° 16'$, Vis. Mag. $= 4.30$, type G5,] was announced as a spectroscopic binary in Lick Obs. Bulletin, Vol. IV, page 107. Four spectrograms were made at the Lick Observatory from 1903 to 1906. Three additional spectrograms were made at the Bonn Observatory from 1909 to 1912. The star was placed on the observing list at Ottawa in December of 1916 in the hope that the range might prove large enough to permit its orbit being obtained with one prism dispersion. Twenty-six plates were secured in the early months of 1917, but these did not seem sufficient to give accurate elements and it was therefore left to be finished from observations with the 72-inch reflector at Victoria.

The determination of the period has proved to be difficult. Fifty-one observations have been secured here and these are in harmony with a period of 9.590 days. This same period will satisfy the Ottawa observations in 1917 very well and the Bonn Observations in 1909 and 1912. The residuals are somewhat larger than one would be led to expect from the fine quality of the spectrum but on the whole they indicate that the period 9.590 days is satisfactory. The Lick observations taken in 1913 to 1916 could not be made to agree and it would seem that there are peculiarities in the orbit not yet explained. The double amplitude of the curve is twenty-three kilometers only and the irregularities in the curve are of the order of five kilometers or a little over so that the complete investigation with one prism dispersion would prove a difficult task. Three prism dispersion would be much better but until such is available the present elements serve as a good approximation to give the general form of the curve.

In the table of observations which follows, the plates taken at Ottawa were measured with the Tœpfer measuring machine, while the Victoria spectrograms were measured on the Hartmann com-

parator with a sky or α Boötis standard. Some of the plates were measured with both standards and seemed to give practically the same result.

Preliminary elements were determined graphically and these used as a basis for a differential correction by the usual method of least squares. The results of the solution are given in Table II.

TABLE OF OBSERVATIONS.

Plate	Observer	Date	Julian Day	Velocity	Wt.	Phase	O−C
Lick		1903, Jan. 4	2,416,119.78	+33.8		0.52	
"		1905, Sept. 27	7,116.01	+19.8		1.83	
"		1906, Oct. 1	7,485.04	+15.8		6.44	
"		" Nov. 9	7,524.98	+19.9		8.02	
Bonn		1909, Jan. 22	8,329.43	+12.3		6.91	−0.9
"		" " 25	8,332.42	+16.9		0.41	−0.7
"		1912, Feb. 7	9,440.38	+21.2		5.42	−1.7
Ottawa							
7950	Y	1916, Dec. 17	2,421,215.624	+19.6	1	6.51	+3.4
7989	"	1917, Jan. 12	1,241.632	+35.0	1	3.75	+6.4
7998	"	" " 16	1,245.683	+ 7.5	1	7.80	+0.3
8013	"	" " 22	1,251.771	+35.6	1	4.30	+8.3
8014	"	" " 26	1,255.469	+12.7	1	8.00	+6.5
8027	"	" Feb. 1	1,261.758	+29.0	1	4.70	+3.0
8044	"	" " 11	1,271.658	+26.4	1	5.01	+1.4
8045	"	" " 11	1,271.708	+27.0	1	5.06	+2.2
8052	"	" " 12	1,272.619	+16.1	1	5.97	−3.9
8049	"	" " 12	1,272.676	+17.5	1	6.03	−2.0
8061	"	" " 15	1,275.762	+15.1	1	9.11	+6.1
8063	"	" " 18	1,278.584	+26.9	1	2.34	−1.7
8064	"	" " 18	1,278.658	+37.7	1	2.42	+9.0
8071	P	" " 24	1,284.517	+ 5.3	1	8.28	−0.5
8073	Y	" " 27	1,287.507	+28.9	1	1.68	+2.3
8082	"	" Mar. 1	1,289.556	+33.8	1	3.73	+5.2
8098	"	" " 6	1,294.562	+ 9.0	1	8.73	+2.2
8099	"	" " 6	1,294.619	+10.4	1	8.79	+3.4
8100	"	" " 6	1,294.674	+ 8.5	1	8.84	+0.8
8110	"	" " 13	1,301.508	+14.1	1	6.09	−5.2
8111	"	" " 13	1,301.561	+14.6	1	6.14	−4.2
8112	"	" " 15	1,303.528	+ 5.0	1	8.11	−1.0
8116	C	" " 16	1,304.641	+16.4	1	9.22	+6.4
8138	Y	" Apr. 8	1,327.528	+29.3	1	3.34	+0.2
8141	"	" " 10	1,329.526	+18.9	1	5.34	−4.7
8142	"	" " 10	1,329.580	+16.6	1	5.39	−6.4
Victoria							
778	Y	1918, Oct. 28	2,421,895.967	+23.5	1	5.97	+3.5
823	"	" " 30	1,897.929	+ 7.7	½	7.93	+1.1
856	"	" Nov. 4	1,902.937	+29.4	1	3.35	+0.3
900	"	" " 20	1,918.894	+13.5	1	0.12	−1.5
901	"	" " 20	1,918.901	+10.9	1	0.13	−4.1
926	"	" " 22	1,920.937	+20.9	1	2.17	+2.7
927	"	" " 22	1,920.951	+30.4	1	2.18	+2.2
988	P	" " 26	1,924.902	+21.7	1	6.13	+2.9
1024	Y	" Dec. 10	1,938.912	+23.9	1	0.96	+1.5
1040	"	" " 14	1,942.925	+28.9	1	4.97	+3.8
1068	"	" " 16	1,944.846	+10.6	1	6.90	−2.7
1098	"	" " 20	1,948.822	+25.7	1	1.28	+1.1
1099	"	" " 20	1,948.828	+24.7	1	1.29	+0.1
1148	P	" " 29	1,957.834	+20.2	1	0.70	−0.1
1149	"	" " 29	1,957.843	+19.3	1	0.71	−1.2
1186	"	" " 31	1,959.785	.....	0	....	.....

TABLE OF OBSERVATIONS—*Continued.*

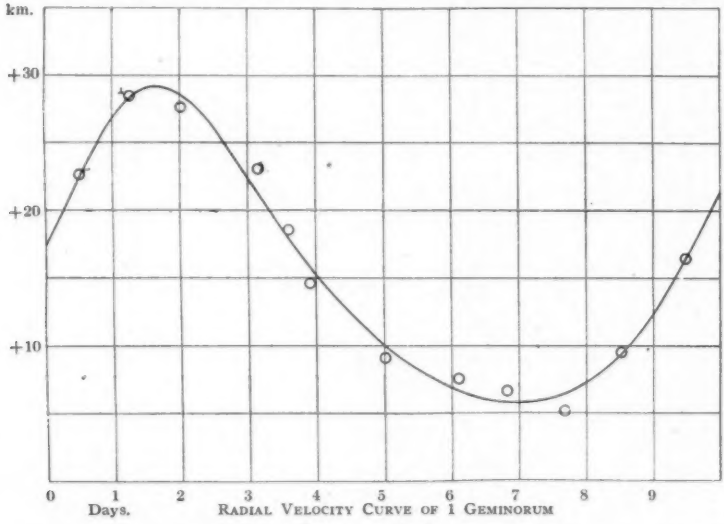
Plate	Observer	Date	Julian Day	Velocity	Wt.	Phase	O−C
Victoria							
1203	Y	1919, Jan. 6	2,421,965.822	+ 4.0	1	8.69	−2.5
1204	"	" " 6	1,965.829	+ 5.4	1	8.70	−1.1
1270	"	" " 10	1,969.803	+27.2	1	3.08	−2.0
1271	"	" " 10	1,969.811	+30.0	1	3.09	+0.8
1272	"	" " 10	1,969.819	+26.1	1	3.10	−3.1
1295	P	" " 19	1,978.782	+26.4	1	2.47	−2.3
1306	Y	" " 29	1,988.719	+26.6	1	2.82	−2.5
1307	"	" " 29	1,988.728	+25.8	1	2.83	−3.3
1327	P	" " 30	1,989.787	+25.2	1	3.89	−3.1
1328	"	" " 30	1,989.795	+24.6	1	3.90	−3.7
1342	Y	" " 31	1,990.741	+27.4	1	4.84	+1.8
1343	"	" " 31	1,990.749	+27.9	1	4.85	+2.3
1369	P	" Feb. 1	1,991.834	+21.1	1	5.93	+0.9
1381	"	" " 2	1,992.714	+12.3	1	6.81	−1.7
1382	"	" " 2	1,992.719	+12.8	1	6.82	−1.2
1391	"	" " 4	1,994.723	+ 9.2	1	8.82	+2.1
1395	Y	" " 5	1,995.584	+13.3	1	0.09	−1.3
1396	"	" " 5	1,995.592	+10.3	1	0.10	−4.3
1397	"	" " 5	1,995.601	+12.0	1	0.11	−2.7
1407	"	" " 5	1,995.800	+13.7	1	0.31	−3.1
1408	"	" " 5	1,995.811	+12.9	1	0.32	−3.9
1409	"	" " 5	1,995.820	+13.3	1	0.33	−3.5
1427	"	" " 11	2,001.772	+17.4	1	6.28	−0.5
1428	"	" " 11	2,001.778	+17.4	1	6.29	−0.5
1448	P	" " 16	2,006.735	+25.0	1	1.66	−1.5
1449	"	" " 16	2,006.742	+26.5	1	1.66	0.0
1477	"	" " 21	2,011.695	+14.4	1	6.61	−1.0
1491	"	" " 23	2,013.749	+ 9.5	1	8.67	+3.0
1492	"	" " 23	2,013.756	+ 9.7	1	8.68	+3.2
1516	"	" Mar. 8	2,026.651	+28.2	1	2.39	−0.5
1559	Y	" " 19	2,037.626	+25.4	1	3.78	−2.8
1583	P	" " 20	2,038.675	+26.8	1	4.82	+1.2
1603	Y	" " 21	2,039.638	+23.3	1	5.79	+2.3
1642	P	" " 23	2,041.722	+ 6.2	1	7.87	−0.5
1643	"	" " 23	2,041.727	+ 7.8	1	7.88	+1.0
1662	Y	" " 24	2,042.625	+ 2.1	1	8.77	−4.7

TABLE II.

	Preliminary	*Final*
Period	9.590 days	9.590 days
Eccentricity	0.20	0.2065 ±.0344
Longitude of periastron	195°.	203°.28 ±6°.80
Semi-amplitude	11.75 km.	11.74 km. ±.33
Velocity of system	+20.13 km.	+19.71 km. ±22.
Time of periastron passage	J.D. 2421898.559	J.D. 2421898.741
$a \sin i$		1,510,000 km.
$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$		.0015 ⊙

The elements are suggestive of those for the Cepheid variables. The period is the shortest yet found for a star of G type if we exclude the Cepheids but is quite normal for a star of that class. The range is small and the eccentricity high for a binary of such short period. The orbit is minute. The observations do not fit

the curve as well as the character of the spectrum would lead one to expect, the probable error of a single plate being, for Victoria, 1.61 km., for Ottawa, 3.00 km. All these characteristics belong also to the Cepheids. On the other hand the star has not been observed to vary, and accepting Adams' value for the parallax and luminosity, $\pi = 0.052$, $L = 6.92\odot$, the absolute magnitude $= +2.82$. According to Shapley's curve in the Astronomical Society of the Pacific *Publication*, February, 1918, for the Cepheid variables, a star of this period and apparent magnitude should have an absolute



RADIAL VELOCITY CURVE OF 1 GEMINORUM

magnitude of −3.0. The writer suspected the spectrum to vary somewhat from F8 to G5 or K, but on making estimates of the relative intensities of the pairs of lines used by the Mount Wilson Observatory for the determination of type, this apparent variation vanished and it was further noticed that the altered appearance of the spectrum depended on the exposure of the plates. Those plates that were normal were all alike but the over exposed plates, of which there were several, had the absorption lines so veiled over as to make the spectrum at first glance resemble an earlier type than it really was.

The general conclusion one would be led back to is, that the star is probably not a Cepheid variable but that it is a G type binary with the shortest period yet found, and that the discrepancies in the earlier observations render it advisable to investigate the star further when higher dispersion is available.

DOMINION OBSERVATORY,
VICTORIA, B.C.
July, 1919.

ORBIT OF THE SPECTROSCOPIC BINARY. BOSS 4669

By Reynold K. Young

The star [$\alpha(1900) = 18h\ 02.1m$, $\delta\ 29°\ 46'$, Vis. Mag. 5.71, type A2] was announced as a binary by the Mount Wilson Observatory in the publications of the Astronomical Society of the Pacific, Volume 29, p. 259. It was also independently discovered to have a variable radial velocity from four plates taken with the 72-inch reflector in 1918. Since then we have obtained twenty-seven additional spectrograms as shown in the journal of observations below.

OBSERVATIONS OF BOSS 4669

Plate	Date	Julian Day	Velocity	No. of lines	Wt.	Phase from J. D., 2,422,048	O-C
Mt. Wilson	May 25/13	2,419,913.959	+7			9.435	+1
" "	June 16	9,935.899	+23			2.539	+4
" "	July 11	9,960.912	−11			8.328	−4
" "	July 2/17	2,421,412.913	+5			8.917	+8
" "	Sept. 5	1,477.736	−9			6.456	+1
Ottawa	Sept. 24	1,496.551	−8. 6			6.047	−1.4
"	Sept. 26	1,498.557	−9. 8			8.053	−0.4
Mt. Wilson	Sept. 29	1,501.646	+42			1.530	+3
Victoria							
227	June 24/18	2,421,769.846	+39. 4	13	1	0.594	+1.4
321	July 11	1,786.831	−10. 9	13	1	7.967	−1.4
502	August 27	1,833.654	− 9. 8	15	1	6.730	−0.8
631	Sept. 20	1,857.672	+28. 6	8	1	1.912	+1.9
1779	April 8/19	2,057.022	− 3.25	18	1	9.022	−1.1
1807	April 14	2,063.001	− 4.43	15	1	5.389	+0.1
1832	April 14	2,063.983	− 3.41	14	½	6.371	+4.1
1850	April 21	2,070.968	+ 3.18	14	1	3.744	−2.3
1867	April 22	2,071.988	+ 0.15	16	1	4.764	+1.5
1913	" 30	2,079.001	+22.60	10	1	2.166	−2.6
1928	May 2	2,081.977	− 3.77	14	1	5.142	−0.6
1958	" 4	2,083.962	− 7.98	17	1	7.127	+1.7
1988	" 6	2,085.988	− 0.00	15	1	9.153	+0.1
1994	" 9	2,088.848	+19.33	11	1	2.400	−2.0
2011	" 10	2,098.916	+17.35	18	1	2.856	+2.7
2026	" 20	2,099.934	+ 4.21	17	1	3.874	−0.3
2036	" 22	2,101.929	− 7.77	10	1	5.869	−1.2
2064	June 1	2,111.870	− 9.14	14	1	6.198	−1.5
2073	" 2	2,112.892	− 9.62	19	1	7.220	+0.2
2088	" 3	2,113.944	− 8.25	16	1	8.272	−0.7
2098	" 4	2,114.908	+ 1.79	15	1	9.236	+0.3
2110	" 6	2,116.849	+40.60	15	1	1.565	+2.5
2113	" 6	2,116.931	+37.80	14	1	1.647	+1.3
2119	" 9	2,119.866	+ 0.41	16	1	4.582	+0.7
2132	" 14	2,124.799	+ 8.19	13	1	9.515	−0.3
2148	" 17	2,127.886	+14.72	16	1	2.990	+1.6
2176	" 24	2,134.803	+23.73	8	1	9.907	−0.2
2180	" 24	2,134.902	+27.24	14	1	0.394	−1.5
2349	July 13	2,153.806	+15.96	14	1	9.686	+1.7
2365	" 14	2,154.746	+46.30	16	1	1.014	−0.9
2376	" 14	2,154.911	+45.70	15	1	1.179	−0.3

Two observations taken at Ottawa by Mr. Harper are also available. The early observations, those taken in 1913 and 1917 at Mount Wilson and Ottawa, were made use of in determining the period only. The spectrum is particularly well suited for accurate measurement. Numerous lines of iron and other well-known elements such as calcium, magnesium, strontium, hydrogen, titanium are present. In general about fifteen of the sharpest lines were selected for measurement. The residuals which result from the comparison of the measurements with the computed values from the final elements are found in the table of observations under the heading O–C. Considering the dispersion employed (35 A. per mm at Hα) they are satisfactorily small, yielding a probable error for a single plate of 1.0 km.

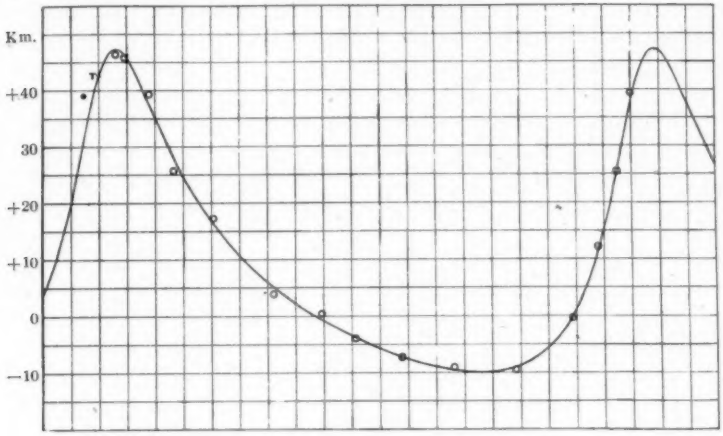
The computation of the orbital elements presents no serious difficulties. All the observations fit a simple elliptic curve and there is no trouble in connecting the early observations with the more recent ones. The period was found by trial and finally fixed at 9.6120 days. It is not subject to an uncertainty of more than .0004 day. The observations were next grouped into fifteen normal places.

NORMAL PLACES

	Phase from J.D. 2,422,048	Velocity	Wt.	O–C Preliminary	O–C Final	Σpv^2 Preliminary	Σpv^2 Final
1	0.344	+25.48	2	−1.27	−0.87	1.61	0.76
2	0.594	+39.40	1	+1.27	+1.40	0.80	0.98
3	1.014	+46.30	1	−0.80	−0.85	0.32	0.36
4	1.179	+45.70	1	−0.36	−0.25	0.07	0.03
5	1.606	+39.20	2	+1.22	−1.82	1.49	3.31
6	2.039	+25.60	2	−3.21	−2.36	10.30	5.57
7	2.749	+17.13	3	+0.03	+0.89	0.00	0.79
8	3.809	+ 3.70	2	−2.05	−1.41	4.20	1.99
9	4.673	+ 0.28	2	+0.70	+1.11	0.49	1.23
10	5.265	− 4.10	2	−0.47	−0.14	0.22	0.02
11	6.101	− 7.46	2½	−0.36	−0.21	0.16	0.05
12	7.026	− 9.13	3	+0.34	+0.33	0.18	0.15
13	8.120	− 9.58	2	−0.44	−0.55	0.19	0.30
14	9.137	− 0.49	3	−0.26	−0.12	0.11	0.02
15	9.600	+12.07	2	+0.31	+0.66	0.10	0.44

The weights in column four indicate the number of plates in a normal place. These were divided by two in forming the observation equations so as to reduce them to an average value near unity. Preliminary elements were determined from the normal places by Dr. King's graphical method. The column headed O–C

Preliminary in the table of normal places gives the comparison of the observations with these elements. Σpv^2 is 20.2 for the preliminary elements, and the final elements, which are the result of a least square solution, reduces this to 16.6.



RADIAL VELOCITY CURVE OF BOSS 4669

TABLE OF ELEMENTS.

	Preliminary	*Final*	
Period	9.6120 days	9.6120 days	±.0004
Eccentricity	0.46	0.4684	±.0083
Longitude of periastron	325°	326°.43	±.85
Time of Periastron Passage	J.D.2,422,048.697	J.D.2422048.711	±0110
Velocity of the system	7.88 km.	7.54 km.	±.23
Semi-amplitude	28.5 km.	28.49 km.	±.37
$a \sin i$ =		3,330,000 km.	
$\frac{m_1^3 \sin^3 i}{(m+m_1)^2}$ =		.016 ⊙	

In the radial velocity curve the initial phase, zero days, is taken as periastron.

DOMINION OBSERVATORY,
VICTORIA, B.C.
July, 1919.

MAGNETIC SURVEY REPORT, 1918.

By C. A. FRENCH.

THE field work of the magnetic survey of Canada was resumed during the summer of 1918 after an interruption of one season. According to the program of operations for the season observations were to be confined to stations previously occupied for the purpose of securing secular variation data. The selection of stations proved fortunate as very few of the old sites were disturbed. In cases where a station was found to be disturbed or seemed likely to be unsuitable for future observations a new point was selected and occupied.

During the season thirty-seven stations were occupied besides a second station at each of four places. In addition to this spring and fall observations were taken at Ottawa as well as comparison observations at the Standard Magnetic Observatory at Agincourt, the comparison observations being for the purpose of determining the correction to reduce the observed values to the International Magnetic Standard. The area covered by the operations during the season is included between Longitude 60° and 97°.2 and Latitude 44°.6 and 50°.2.

The instruments used throughout the season were the same as were used during 1916, namely, the half-seconds chronometer Bond No. 511 and magnetometer C.I.W. No. 20.

The method of observing as well as the method of reducing the observations to obtain a mean value of each of the three magnetic elements was similar to that employed in previous years.

The results of all the standardizing comparisons, at present on record in this office, made between magnetometer No. 20 and various magnetic instruments are summarized in Tables A and B.

TABLE A. I. M. S.—No. 20.

DATE	DECLINATION	HORIZONTAL INTENSITY. c.g.s.	REMARKS
March, 1915	−0.7	−0.00023H	Determined at Washington, D.C.
May, 1916	−0.9	−0.000084	Determined at Agincourt
October, 1916	−0.9	−0.000071	Determined at Agincourt
Mean 1916	−0.9	−0.000078 = −0.00048H	
October, 1918	−0.9	−0.000017 = −0.00011F	Determined at Agincourt.

TABLE B. I. M. S.—No. 20.

*Inclination.				Remarks.
Needle No. 1	Needle No. 2	Needle No. 5	Needle No. 6	
′	′	′	′	
−0.7	−0.2	−0.0	1.4	Determined at Washington in 1915.
−1.5	−1.0	−0.4	1.2	Determined at Ottawa in 1916.
−1.6	−1.4	0.0	0.8	Determined at Ottawa in 1917.

*The standard instrument for inclination comparisons made at Ottawa was the D.O. earth inductor Toepfer No. 1911.

MAGNETIC RESULTS, 1918.

Station.	Lat.	Long.	Date.	Declin.	Range of Dec	Dip.	Hor. Int.	Total Int.
	° ′	° ′		° ′	′	° ′	c.g.s.	c.g.s.
Ottawa.....	45 23.6	75 43.0	Apr. 15–18	13 33.4	12.2	75 40.6	.14896	.60212
			May 20–22	34.5	16.4	41.4	.14893	.60255
Maniwaki	46 22.5	75 58.6	May 29, 30	14 14.5	18.6	76 28.6	.14147	.60498
Terrebonne	45 42.8	73 39.8	June 5, 6	15 21.6	20.7	75 49.4	.14666	.59883
(*a*) Rivière du Loup, B.	47 51.6	69 33.2	June 8–14	21 28.4	17.2	76 26.5	.14012	.59769
Rivière du Loup, A	47 51.6	69 33.2	June 11–14	21 24.2	13.5	76 27.4	.13971	.59659
Matapedia	47 58.5	66 57.0	" 17, 18	23 37.3	13.8	76 21.4	.13884	.58861
Moncton	46 05.0	64 47.2	" 19, 20	22 59.2	16.4	74 55.5	.15115	.58116
Halifax	44 37.6	63 34.5	" 24, 25	21 58.4	15.6	73 47.3	.16021	.57385
Annapolis	44 45.0	65 31.2	" 26, 27	21 09.3	17.4	73 58.7	.15975	.57880
Truro	45 21.3	63 16.6	" 29, 30	22 48.0	15.6	73 45.0	.16145	.57696
Sydney	46 08.8	60 11.6	July 3– 5	25 53.3	14.2	74 05.0	.15613	.56932
Charlottetown	46 14.0	63 07.3	" 9, 10	24 17.2	18.0	74 44.8	.15250	.57966
St. John	45 16.8	66 02.5	" 13, 14	21 07.4	15.2	74 16.1	.15796	.58259
Woodstock	46 09.6	67 34.8	" 15, 16	20 36.9	15.0	75 24.4	.14768	.58613
Quebec	46 48.0	71 15.2	" 17, 18	18 50.8	18.0	75 54.4	.14590	.59917
Three Rivers	46 21.0	72 32.8	" 19, 20	16 21.1	15.4	75 55.3	.14594	.59996
(*b*) Chicoutimi, B.	48 25.4	71 03.9	" 22, 23	20 50.6	18.0	77 25.0	.13136	.60296
Chicoutimi, A	48 25.4	71 03.9	" 23	21 08.6	19.6	77 17.4	.13250	.60223
(*c*) La Tuque, A	47 26.8	72 48.0	" 25–27	16 58.6	24.9	76 47.6	.13694	.59939
La Tuque, B	47 26.8	72 48.0	" 27	16 29.4	17.9	76 39.2	.13862	.60050
Parent	47 55.4	74 37.9	" 29, 30	15 12.6	13.6	77 30.5	.13126	.60685
Doucet	48 13.8	76 33.4	" 31	14 30.9	17.8	77 39.0	.13064	.61080
O'Brien	48 40.2	78 41.3	Aug. 1, 2, 3	12 29.8	28.1	78 06.2	.12605	.61146
Cochrane	49 04.0	81 01.6	" 5– 8	9 37.2	20.5	78 24.7	.12362	.61540
(*d*) Liskeard, A	47 30.6	79 41.8	" 10–13	9 30.5	21.2	77 30.8	.13218	.61134
Liskeard, B	47 30.6	79 41.8	" 13	9 36.7	15.6	77 29.2	.13210	.60969
Hearst	49 40.8	83 39.2	" 15–17	5 02.0	29.7	79 01.1	.11842	.62155
Grant	50 07.5	86 17.7	" 19–21	2 58.2	25.4	79 19.1	.11568	.62508
				East.				
Armstrong	50 18.5	89 02.0	" 22, 23	0 35.2	24.6	79 36.0	.11394	.63118
Sioux Lookout	50 05.5	91 55.0	" 24–26	5 25.2	26.4	78 46.5	.12139	.62359
Redditt	49 59.2	94 23.0	" 27–29	8 56.8	15.6	78 37.6	.12431	.63037
Winnipeg	49 51.9	97 07.7	Sept. 2, 3	13 29.6	17.2	78 09.3	.12925	.62967
Rainy River	48 43.3	94 34.6	" 4, 5	9 03.2	14.3	77 30.5	.13494	.62386
Atikokan	48 45.3	91 37.8	" 6, 7	5 09 2	24.1	77 39.6	.13302	.62242
Twin City Junct.	48 22.3	89 24.5	" 9, 10	2 36.7	19.2	77 52.3	.13088	.62294
				West.				
Schreiber	48 48.5	87 16.5	" 11, 12	1 08.6	16.2	78 25.1	.12456	.62043
White River	48 35.2	85 16.5	" 13, 14	4 17.1	13.4	78 14.8	.12655	.62126
Chapleau	47 50.3	83 24.4	" 16, 17	4 55.4	16.4	77 51.5	.13012	.61865
Sault Ste. Marie	46 30.9	84 17.7	" 19, 20	3 37.7	15.0	77 01.2	.13917	.61960
Algoma	46 11.4	82 48.8	" 22, 23	5 27.8	20.0	76 35.2	.14229	.61296
Mattawa	46 19.5	78 42.5	" 25, 26	9 38.3	9.4	76 43.4	.14046	.61162
Chalk River	46 00.8	77 27.4	" 27	11 25.8	5.2	76 22.6	.14298	.60704
Ottawa	45 23.6	75 43.0	Oct. 3–10	13 36.5	17.3	75 42.2	.14854	.60152

(*a*) Station B, which was selected for the Eclipse observations, is 429 feet north easterly from the C.I. station of 1907 and designated as Station A.

(*b*) Station A is approximately a re-location of the C.I. station of 1906 and is 167 feet northerly from Station B.

(*c*) Station A is an exact re-location of the station of 1914 and is 560 feet south of Station B.

(*d*) Station A is identical with the station of 1913 and is about 754 feet south-easterly from station B, which is a re-location of the C.I. station of 1909.

TABLE I.

Station.	Lat.	Long.	Date.	Declin.	Dip.	Hor. Int.
	° ′	° ′		West ° ′	° ′	c.g.s.
Sydney	46 09	60 12	1905.7	25 10	74 23	.1565
			1908.5	25 22	74 14	.1570
			1909.6	25 28	74 12	.1572
Charlottetown	46 14	63 07	1908.8	23 47	74 59	.1535
Truro	45 21	63 16	1907.8	21 52	73 52	.1616
Halifax	44 38	63 34	1905.7	20 47	73 59	.1619
			1911.7	21 35	73 50	.1615
Black Point	44 39	63 59	1905.7	21 01	74 00	.1619
Moncton	46 05	64 47	1907.8	22 15	75 08	.1515
Annapolis	44 50	65 31	.....	.....	.....	.....
St. John	45 17	66 08	1905.7	20 43	74 23	.1609
St. John	45 17	66 03	1907.8	20 11	74 25	.1592
Matapedia	47 58	66 57	1907.9	22 53	76 35	.1387
Woodstock	46 00	67 35	.....	.....	.....	.....
Riviere du Loup	47 52	69 33	1906.7	20 39	76 34	.1407
Chicoutimi	48 25	71 04	1906.7	20 17	77 37	.1333
Quebec	46 18	71 15	1905.7	17 49	76 03	.1473
	.....	.....	.....	.....	.....	.....
	.....	.....	1906.7	17 53	75 59	.1478
	.....	.....	1909.7	18 20	76 01	.1477
			1909.8	18 15	76 03	.1471
Three Rivers	46 21	72 33	1906.7	15 26	75 57	.1482
La Tuque	47 27	72 48	.....	.....	.....	.....
Terrebonne	45 43	73 40	.....	.....	.....	.....
Parent	47 55	74 48	.....	.....	.....	.....
Ottawa	45 24	75 43	1906.8	12 44	75 38	.1521
	.....	.....	1907.4	12 37	75 41	.1503
	.....	.....	1908.9	12 50	75 42	.1513
	.....	.....	1908.9	12 52	.....	.1514
	.....	.....	1909.6	13 00	75 39	.1512
	.....	.....	1910.5	13 04	75 40	.1509
	.....	.....	1911.6	13 09	75 40	.1508
Doucet	48 14	76 33	.....	.....	.....	.....
Chalk River, A	46 01	77 27	1906.8	10 20	76 24	.1460
Chalk River, B	46 01	77 27	.....	.....	.....	.....
O'Brien	48 40	78 41	.....	.....	.....	.....
Mattawa	46 20	78 43	1908.8	8 51	76 40	.1430
Liskeard, A	47 31	79 42	.....	.....	.....	.....
Liskeard, B	47 31	79 42	1909.5	8 47	77 34	.1339
Cochrane	49 04	81 02	.....	.....	.....	.....
Algoma	46 11	82 49	1906.8	4 35	76 24	.1466
Chapleau	47 50	83 24	1906.8	4 04	77 51	.1328
	.....	.....	.....	.....	.....	.....
Hearst	49 41	83 39	.....	.....	.....	.....
Missinaibi	48 19	84 07	1905.7	5 19	77 55	.1322
	.....	.....	1906.7	5 39	77 52	.1329
Sault Ste. Marie	46 37	84 18	.....	.....	.....	.....
White River	48 35	85 17	1906.7	3 01	78 16	.1289
Grant	50 08	86 18	.....	.....	.....	.....
Schreiber	48 49	87 17	1906.7	0 22	78 25	.1270
				East		
Nipigon	49 01	88 16	1906.7	1 18	78 29	.1273
Armstrong	50 18	89 02	.....	.....	.....	.....
Fort William	48 24	89 15	1910.5	3 16	77 49	.1333
Twin City Junction	48 22	89 25	.....	.....	.....	.....
Savanne	48 57	90 14	1906.7	4 34	78 10	.1303
Atikokan	48 45	91 38	.....	.....	.....	.....
Ignace	49 24	91 40	1906.7	6 15	78 27	.1278
Sioux Lookout	50 06	91 54	.....	.....	.....	.....
Eagle	49 48	93 11	1906.7	6 40	78 08	.1313
Redditt	49 59	94 23	.....	.....	.....	.....
Kenora	49 46	94 29	1906.7	9 54	77 59	.1317
Rainy River	48 43	94 35	1906.8	9 34	77 27	.1376
Winnipeg	49 52	94 09	1906.7	13 56	78 08	.1315
	.....	.....	1907.5	13 54	78 10	.1305
	.....	.....	1908.4	13 59	78 08	.1309
	.....	.....	1908.5	13 57	78 13	.1310
	.....	.....	1910.6	13 56	78 11	.1305

TABLE I—Cont.

Station.	Date.	Declin.	Dip.	Hor. Int.	Date	Declin.	Dip.	Hor. Int.
		West ° ′	° ′	c.g.s.		West ° ′	° ′	c.g.s.
Sydney	.....	.....	.....	.....	.....	.....	.....	.....
	1912.8	25 44	74 12	.1567	1918.5	25 53	74 05	.1561
Charlottetown	.....	.....	.....	.....	.....	.....	.....	.....
Truro	1912.7	22 32	73 52	.1626	1918.5	24 17	74 45	.1525
Halifax	1912.6	21 39	73 52	.1613	1918.5	22 48	73 51	.1614
						21 58	73 47	.1602
Black Point	1912.6	21 42	73 54	.1615	.....	.....	.....	.....
Moncton	1912.6	22 43	75 02	.1521	1918.5	22 59	74 55	.1512
Annapolis	1912.7	20 50	74 04	.1609	1918.5	21 09	73 58	.1598
St. John	1909.6	21 08	74 21	.1605	.....	.....	.....	.....
St. John	1912.8	20 49	74 22	.1591	1918.5	21 07	74 16	.1580
Matapedia	1912.5	23 22	76 29	.1394	1918.5	23 37	76 21	.1388
Woodstock	1912.8	20 16	75 29	.1488	1918.5	20 37	75 24	.1477
Riviere du Loup	1912.5	21 08	76 34	.1405	1918.4	21 24	76 27	.1397
Chicoutimi	1913.4	20 57	77 25	.1329	1918.6	21 09	77 17	.1325
Quebec	1913.4	18 33	75 57	.1470	.....	.....	.....	.....
	1912.6	18 30	75 57	.1472	1918.6	18.51	75 54	.1459
	1914.4	18 38	75 55	.1468	.....	.....	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....
Three Rivers	1912.4	16 01	75 58	.1476	1918.6	16 21	75 55	.1459
La Tuque	1914.4	16 44	76 51	.1380	1918.6	16 59	76 48	.1369
Terrebonne	1912.4	14 55	75 51	.1485	1918.4	15 22	75 49	.1467
Parent	1914.4	15 00	77 34	.1315	1918.6	15 13	77 30	.1313
Ottawa	1912.6	13 13	75 40	.1506	1918.6	13 35	75 42	.1487
	1913.6	13 18	75 42	.1503	.....	.....	.....	.....
	1913.8	13 16	75 41	.1503	.....	.....	.....	.....
	1914.6	13 22	75 41	.1499	.....	.....	.....	.....
	1915.6	13 26	75 42	.1495	.....	.....	.....	.....
	1916.6	13 30	75 42	.1493	.....	.....	.....	.....
	1917.6	13 33	75 41	.1490	.....	.....	.....	.....
Doucet	1914.5	14 15	77 40	.1312	1918.6	14 31	77 39	.1306
Chalk River, A	1913.5	10 57	76 21	.1447	.....	.....	.....	.....
Chalk River, B	1913.5	11 01	76 22	.1447	1918.7	11 26	76 23	.1430
O'Brien	1914.5	12 17	78 10	.1266	1918.6	12 30	78 06	.1260
Mattawa	1909.5	8.54	76 40	.1428	1918.7	9 38	76 43	.1405
Liskeard, A	1913.5	9 12	77 32	.1331	1918.6	9 31	77 31	.1322
Liskeard, B	.....	.....	.....	.....	1918.6	9 37	77 29	.1321
Cochrane	1913.5	9 18	78 29	.1244	1918.6	9 37	78 25	.1236
Algoma	1916.4	5 17	76 32	.1433	1918.7	5 28	76 35	.1423
Chapleau	1913.6	4 31	77 53	.1314	.....	.....	.....	.....
	1910.4	4 17	77 52	.1321	1918.7	4 55	77 52	.1301
Hearst	1914.6	4 48	79 02	.1192	1918.6	5 02	79 01	.1184
Missinaibi	1910.4	5 50	77 50	.1326	.....	.....	.....	.....
	1910.4	5 50	77 50	.1326	.....	.....	.....	.....
Sault Ste. Marie	1916.5	3 33	76 59	.1398	1918.7	3 38	77 01	.1392
White River	1910.4	3 13	78 19	.1276	.....	.....	.....	.....
Grant	1914.6	2 43	79 21	.1164	1918.6	2 58	79 19	.1159
Schreiber	1910.4	0 33	78 26	.1261	1918.7	1 09	78 25	.1246
		East				East		
Nipigon	1910.4	1 06	78 30	.1264	.....	.....	.....	.....
Armstrong	1914.6	0 48	79 39	.1140	1918 7	0 35	79 36	.1139
Fort William	1916.6	2 52	77 51	.1315	.....	.....	.....	.....
Twin City Junction	1916.6	2 42	77 53	.1311	1918.7	2 37	77 52	.1309
Savanne	1910.5	4 27	78 12	.1294	.....	.....	.....	.....
Atikokan	1914.8	5 20	77 42	.1338	1918.7	5 09	77 40	.1330
Ignace	1910.5	6 10	78 30	.1266	.....	.....	.....	.....
Sioux Lookout	1914.7	5 14	79 14	.1183	1916.7	5 06	79 14	.1178
Eagle	1910.6	6 34	78 10	.1305	.....	.....	.....	.....
Redditt	1914.7	9 10	78 41	.1249	1918.7	8 57	78 38	.1243
Kenora	1910.6	9 59	77 59	.1311	.....	.....	.....	.....
Rainy River	.....	.....	.....	.....	1918.7	9 03	77 30	.1349
Winnipeg	1911.7	13 51	78 13	.1299	1918.7	13 30	78 09	.1293
	1913.6	13 47	78 11	.1299	.....	.....	.....	.....
	1914.7	13 42	78 12	.1296	.....	.....	.....	.....
	1915.8	13 39	78 12	.1294	.....	.....	.....	.....
	1916.7	13 35	78 10	.1293	.....	.....	.....	.....

TABLE I—Cont.

Station.	Average Annual Change.							
	Mean Date	Dec.	Dip.	H. I.	Mean Date	Dec.	Dip.	H. I.
		′	′	γ		′	′	γ
Sydney								
	1910.6	−5.1	−1.4	− 7	1915.6	−1.6	−1.2	−11
Charlottetown	(1913.6	−3.0	−1.4	−11)				
Truro	1910.2	−8.2	0.0	+20	1915.6	−2.7	−0.2	−21
Halifax	1909.2	−7.5	−1.0	− 9	1915.6	−3.2	−0.7	−19
Black Point	1909.2	−5.9	−0.9	− 6				
Moncton	1910.2	−5.8	−0.6	+12	1915.6	−2.7	−1.2	−15
Annapolis					1915.6	−3.3	−1.0	−19
St. John	1907.6	−6.4	−0.5	−10				
St. John	1910.3	−7.6	−0.6	− 2	1915.6	−3.2	−1.1	−19
Matapedia	1910.2	−6.3	−1.3	+15	1915.5	−2.5	−1.3	−10
Woodstock					1915.6	−3.7	−0.9	−19
Riviere du Loup	1909.6	−5.0	0.0	− 3	1915.4	−2.7	−1.2	−14
Chicoutimi	1910.0	−6.0	−1.8	− 6	1916.0	−2.3	−1.3	− 8
Quebec	1909.6	−5.7	−0.8	− 4				
					1915.6	−3.5	−0.5	−22
Three Rivers	1909.6	−6.1	+0.2	−11	1915.5	−3.2	−0.5	−27
La Tuque					1916.5	−3.6	−0.7	−26
Terrebonne					1915.4	−4.5	−0.3	−30
Parent					1916.5	−3.1	−1.0	− 5
Ottawa	1909.7	−5.0	+0.3	−26	1915.6	−3.7	+0.3	−32
Doucet					1916.6	−3.9	−0.2	−15
Chalk River, A	1910.2	−5.5	−0.4	−19				
Chalk River, B					1916.1	−4.8	+0.2	−33
O'Brien					1916.6	−3.2	−1.0	−15
Mattawa	(1913.8	−4.7	+0.3	−25)	(1914.1	−4.8	+0.3	−25)
Liskeard, A					1916.0	−3.7	−0.2	−18
Liskeard, B					(1914.0	−5.5	−0.5	−20)
Cochrane					1916.0	−3.7	−0.8	−16
Algoma	1911.6	−4.3	−0.8	−34	1917.6	−4.8	−1.3	−43
Chapleau	1910.1	−4.0	+0.3	−21				
					1915.6	−4.6	0.0	−24
Hearst					1916.6	−3.5	−0.2	−20
Missinaibi	1908.0	−6.6	−1.1	+ 9				
	1908.6	−3.0	−0.6	− 8				
Sault Ste. Marie					1917.6	−2.3	+1.0	−27
White River	1908.6	−3.2	+0.8	−35				
Grant					1916.6	−3.8	−0.5	−12
Schreiber	1908.6	−3.0	+0.3	−24	1914.6	−4.3	−0.1	−18
Nipigon	1908.6	−3.2	+0.3	−19				
Armstrong					1916.6	−3.2	−0.7	− 2
Fort William	(1913.6	−3.9	+0.3	−30)				
Twin City Junction					1917.6	−2.4	−0.5	−10
Savanne	1908.6	−1.8	+0.6	−24				
Atikokan					1916.8	−2.8	−0.5	−21
Ignace	1908.6	−1.3	+0.8	−32				
Sioux Lookout					1915.7	−4.0	0.0	−30
Eagle	1908.6	−1.5	+0.5	−21				
Redditt					1916.7	−3.2	−0.8	−15
Kenora	1908.6	+1.3	0.0	−15				
Rainy River	1912.8	−2.6	+0.3	−23				
Winnipeg	1909.2	−1.0	+1.0	−32	1915.2	−3.0	−0.6	−9
	1910.6	−1.1	+0.2	−10				

The results of the observations for the season 1918 are given in the accompanying table. These have all been reduced to the International Magnetic Standard by applying to the observed values the following corrections: 0′.9 for declination, −0.00011H for horizontal intensity, and −1′.5, −1′.0, −0′.4 and 1′.2 for values of inclination obtained with needles No. 1, No. 2, No. 5 and No. 6 respectively.

TABLE II.

Longitude.	Rate of Annual Change for Epoch.							
	1909.6				1916.0			
	Mean Lat.	Dec.	Dip.	H.I.	Mean Lat.	Dec.	Dip.	H.I.
	°	′	′		°	′	′	
60 to 65	45.6	−6.5	−0.8	+ 2	45.5	−2.6	−0.8	−16
65 " 70	47.0	−6.3	−0.6	0	46.3	−3.1	−1.1	−16
70 " 75	47.0	−5.9	−0.8	− 6	47.0	−3.4	−0.7	−20
75 " 80	45.7	−5.2	0.0	−22	47.2	−3.9	−0.3	−20
80 " 85	47.5	−4.5	−0.6	−14	47.9	−3.8	−0.3	−26
85 " 90	48.8	−3.1	+0.4	−26	49.4	−3.4	−0.4	−10
90 " 95	49.3	−0.8	+0.5	−23	49.6	−3.2	−0.2	−22
95 " 100	49.9	−1.0	+0.6	−21	49.9	−3.0	−0.6	− 9

Secular Change.

The results of the observations taken at repeat stations since 1909 in the area covered by the operations of the past season are given in Table I. The majority of the earlier observations and a few of the later were taken by officials of the Carnegie Institution of Washington, the results for 1911.7 by W. E. W. Jackson of the Meteorological Service and the remainder by observers of the Dominion Observatory. The stations are arranged in the order of increasing longitude, and the results are grouped in three divisions. The first contains observations whose dates range from 1905.5 to 1910.5, the second from 1909.5 to 1916.7, and in the third are included all the observations taken in 1918. Under "Average Annual Change" are two sets of values for each of the elements and corresponding to each of these is the mean date for the period to which the average annual change applies. For example, the change in declination at Sydney between 1908.5 and 1912.8, a period of 4.3 years, amounted to 22′ or an average annual change of 5′.1 for the period, the mean date of which is 1910.6.

The purpose in thus arranging the results was mainly to make easy a comparison between the values of the annual change of the elements for the two periods. It will be noted that in a few cases the values of the annual change apply to neither the first nor the second period but rather to both. These values are included in brackets and are omitted from the brief discussion which follows. The mean of the dates of the first series of values of the annual change is 1909.6 and of the second 1916.0.

On examining the results given under "Average Annual Change" it is seen that there is a marked diminution of the values for declination for the second period, or for the epoch 1916.0, over that for the first, at least for the eastern stations. For the first epoch there appears to be a gradual decrease in the values of declination in proceeding from eastern to western stations. For the second epoch there is a minimum value for eastern stations, a gradual increase until a maximum is reached then a slight decrease. With the dip and horizontal intensity there appears very little evidence of a marked variation either for difference of longitude or epoch. The conditions are possibly better represented by the data given in Table II, which is summary of the results given under "Average Annual Change" in Table I. Each value given in this table is the mean of all the values of the corresponding element at stations distributed over the area included between every fifth degree of longitude beginning with 60°. For the epoch 1909.6 the values of the declination change exhibit a fairly uniform decrease, as was mentioned above, though the regularity is interrupted by the value for longitude 90° to 95°. This value is probably unduly influenced by one discordant value (Kenora) included in the group. The results indicate that the dip is decreasing in the east and increasing in the west, and the decrease in horizontal intensity is less in the east than in the west. For the epoch 1916.0 the declination increases slightly between 60° and 80° after which it decreases somewhat; the dip is decreasing by a small amount at all points and the horizontal intensity exhibits a slight increase in proceeding from east to west then a decrease, though the values do not manifest the regularity that one might desire.

In conclusion it may be stated that the results as given here are not considered final especially in regard to the distribution of the

values of the average annual change. No account has been taken of the probable variation for change in latitude. From the data available it is intended to construct a table of secular changes for the two periods to cover the area under consideration. A method that suggests itself as being a suitable one, is to divide the area into, say three or four, districts and represent the values in each district as a linear function of the latitude and longitude, thus forming a series of conditional equations from which a least square solution may be made. The table having been constructed, the necessary data for reducing observations to a common epoch, may be readily obtained.

In the following tables it is to be noted that:—

(1) A negative sign before the numerical values expressing the average annual change of declination indicates that west declination is increasing and east declination decreasing, west declination being considered negative and east positive.

(2) $1\gamma = 0.00001$ c.g.s.

DOMINION OBSERVATORY, OTTAWA.
March 20, 1919.

MEETINGS OF THE SOCIETY

At Toronto

October 7.—The Society held its first meeting of the 1919-20 session at 8 p.m. in the Physics Building of the University of Toronto, the President, Mr. A. F. Miller, in the chair.

Mr. Miller referred to his observation of a bright spot on the outer ring of Saturn, seen on May 13, which he mentioned at the last meeting, his observation having been confirmed since that time by some writers in the *English Mechanic*. He desired to give a more detailed report of his observation of the spot. On that evening the sky was extremely clear and the definition perfect, permitting the use of powers up to 400 with his 4-inch refractor. At 9 p.m. when the telescope was directed at Saturn he saw a very bright spot on Ring A at the extremity of the ellipse on the *following* side just beyond the Cassini division. The spot was so bright and distinct he thought a small star might be suffering occultation, and watched carefully for its appearnce in the division, or for a change of position such as the planet's orbital motion ought to occasion; but as no such appearance could be perceived he continued observing till 11 p.m. for the purpose of detecting motion of the spot due to rotation of the ring if it were an appendage of the latter. However, after two hours watching the spot remained as when first seen. Subsequent observation was not possible till May 18, when, using the same powers under favourable conditions, the spot could not be detected, though the *following* extremity of Ring A appeared somewhat brighter than the *preceding*.

The Recorder reported the items of business transacted at the meeting of the Society's Council on June 25, viz., that agreeably to the request of the Board of Control of Toronto City, a committee to represent the Society consisting of Messrs. A. F. Miller, J. A. Patterson and J. R. Collins was appointed, the University of Toronto having appointed a similar committee; that the estimates of the University Press for the printing of the Society's JOURNAL had been accepted and that reports of progress on some other items did not call for action by the Council.

The report of the Librarian showed that the Society had received a gratifying list of accessions to the library during the summer months, viz., 228 publications.

Reports of observations made by the members during the summer, and a discussion of them, formed the programme of the evening.

Mr. A. F. Miller had frequently noticed groups of sunspots during the summer, using a simple means of projection of the sun's image. It was also reported that a recent writer, Edward M. Nelson, claims that he has observed polar caps on Venus. The rotation of Venus also came up for consideration, and it appears that recent preliminary estimates of the planet's axial rotation by means of the spectroscope do not confirm the conclusion of the Italiam astronomer, Schiaparelli, that the planet rotates in the same period that it takes to revolve around the sun.

Under the head of auroras seen during the summer, the magnetic storm of August 11, and the auroral displays associated with it, occupied most attention.

Mr. J. A. Patterson had observed the display of that date on the coast of New Brunswick. Dr. J. B. Fraser had observed it at Parry Sound, and described its appearance and vivid colouring as remarkable phenomena. The position of the corona sometimes formed at the magnetic zenith also occupied some attention, and Professor Chant explained its formation. Mr. W. E. W. Jackson described the magnetic storm on that occasion as the most intense for this year.

The President, Mr. A. F. Miller, reported some observations he had made on Nova Aquilæ since the early part of last June. He prefaced his remarks by saying that he now believes he underestimated its brightness toward the end of November, 1918. He then considered it of the 7th magnitude, whereas it should probably have been rated brighter. When he again saw it early in June, comparison with three small stars in the same telescope field led to the opinion that its light had diminished very little during the previous six months. He had not been able to obtain determinations of the magnitudes of the three small comparison stars, but the relative light ratios of these objects among themselves and with the Nova did not appear to differ much from those arrived at in November. He had also been unable to detect any noticeable fluctuation in the light emission from night to night by observations made on every possible occasion. He rates the star at present slightly above magnitude 7. The spectrum shows one bright, broad line, or band, which he regards as the principal line of nebulium; a very faint, fine line, less refrangible, may be the second line of the same hypothetical element. Beside these, $H\beta$ can just be glimpsed, and occasionally another very faint line probably due to helium. $H\alpha$ has faded to invisibility. There is also a faint, but perfectly certain, narrow, continuous spectrum, like that of a central nucleus of greater density than the nebulous mass whence the bright line spectrum originates. Almost the entire light of the star is due to its nebulium constituent. The colour of the star is white, slightly bluish. Visually, there is little or no appearance of nebulosity: but the image always has an outstanding greenish white margin, just as the image was bordered with crimson when the red hydrogen line was brilliant.

Mr. Miller had made observations on the conjunction of Venus and Saturn. On July 1, at 9 p.m., the two planets were very close, being just visible at the opposite sides of an eyepiece field slightly exceeding 30′. On July 2, at 9 p.m., the two were distant approximately 20′ and well seen together in the field of the ocular. Dr. Watson had also observed the conjunction.

October 21.—The Society met at 8 p.m. in the Physics Building of the University of Toronto, the President, Mr. A. F. Miller, in the chair.

The following were elected members of the Society:

Gustave Comment, New York, N.Y.

Rev. N. R. D. Sinclair, B.D., Belmore, Ont.

H. S. Harron, Toronto.

Gen. C. H. Mitchell, Dean of the Faculty of Applied Science, University of Toronto.

Mr. J. R. Collins showed some interesting spectrographs of Venus, Jupiter and Saturn, made by the late Professor Percival Lowell for the determination of the rotation of these planets.

The polar caps which a writer in the *English Mechanic*, Mr. Edward M. Nelson, recently claimed to have seen on the planet Venus, received some attention, and in the course of some remarks on this topic the recorder suggested that the phenomenon, if verified by further observations, might be due to auroral outbreaks, similar to those occurring in the polar regions of the earth.

Dr. A. D. Watson reported a brilliant aurora seen by Mrs. Watson at Dauphin, Man., on October 18. Mr. A. F. Miller reported minor displays at Toronto on October 13th and 18th, and the recorder reported an aurora of low altitude seen at Barrie on the night of the 17th.

Mr. A. F. Miller mentioned that he had continued to observe Nova Aquilæ 3 on all possible occasions since his report at the last meeting. The Nova appears to be slowly declining. It is barely visible in the field of a one-inch finder, and he thinks it has now fallen below magnitude 7; colour, white with a slightly bluish shade. He has not detected any noticeable fluctuations of the light for some time past. The spectrum has not materially changed during his later observations. It still shows one broad band (nebulium), and at least two narrow bright lines less refrangible. $H\beta$ has been detected occasionally as a hazy band. The continuous spectrum, which is quite evident, is strongest toward the red, and scarcely visible in the opposite region. He suspects that the broad green band may consist of several close bright lines.

Mr. Miller exhibited a globe of the planet Mars 16 cm. in diameter, which he constructed early last spring, after having read in the *Bulletin de la Société Astronomique de France* that an invalid French lady had presented to M. Camille Flammarion a globe of Mars which she had made as a relief from the monotony of a sick room. Mr. Miller explained that he had located upon it the various distinctive features or markings with much care after the best available charts, supplemented by his own observations and drawings during many oppositions of the planet. In future he proposes to use the globe as an observatory accessory.

Mr. A. F. Miller had observed there were spots on the sun on every clear day since the date of the last meeting.

Mr. H. W. Barker gave the address of the evening on "Pin-hole Photography", illustrating his remarks with a series of lantern illustrations from photographs made by this process. Following closely the rules laid down by the Rev. J. B. Thompson of Greenock, Scotland, in an article on this subject in a photographic magazine, *The Photo-Miniature* for June, 1901, Mr. Barker had constructed a simple camera out of a cigar-box, which he exhibited and explained. The advantages of this method are:

It photographs an object or landscape with geometrical accuracy, no distortion by a lens being introduced into the picture.

There is no need of focusing.

Its cost is extremely small.

A wider angle is obtainable.

Among the disadvantages of the method must be mentioned the length of exposure required.

The specimens shown upon the screen were remarkably good.

A. F. Hunter, *Recorder.*

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada September, 1919.

Temperature—The temperature was above the average from British Columbia to Manitoba. In Ontario the average was exceeded, except well to the northward and northeastward in the Province, while in Quebec and the Maritime Provinces it was from average to a little below. The chief widespread positive departures occurred in the Peninsula of Ontario and in Saskatchewan, and varied between 1° and 5° and 3° and 4° respectively.

Precipitation—In British Columbia the precipitation was well below the average generally, the deficit being marked over the Lower Mainland and in Cariboo. Northern Alberta, Southern Saskatchewan, and Western Manitoba recorded less than usual; in the other parts of the Western Provinces the average was exceeded, Prince Albert and Winnipeg giving marked excesses. In Ontario, over the Peninsula, except in a few counties, the rainfall was generally deficient, elsewhere it was nearly everywhere heavy and especially so from Muskoka northward. Haileybury registered 6.78 inches, Montreal River 6.15 inches, and several places over 5 inches. In Quebec the rainfall was below the average, except in the extreme west and east portions, where positive departures of a half to one and a quarter inches occurred respectively. In the Maritime Provinces in the Bay of Fundy district there was a deficiency, while in the other localities there was an excess of from one to nearly one and a half inches.

TEMPERATURES FOR SEPTEMBER 1919

STATION	SEPTEMBER		STATION	SEPTEMBER.	
	Highest	Lowest		Highest	Lowest
Yukon			*Ontario—continued*		
Dawson	74	22	Kenora	72	31
British Columbia			Kinmount	87	33
Atlin	—	—	Kingston	85	42
Agassiz	86	32	Kitchener	93	37
Barkerville	67	17	London	93	35
Kamloops	84	21	Lucknow	87	33
New Westminster	81	36	Markdale	85	40
Prince Rupert	76	44	North Gower	88	30
Vancouver	79	36	Oshawa	79	40
Victoria	81	42	Ottawa	85	36
Western Provinces			Paris	93	35
Battleford	82	24	Parry Sound	86	34
Calgary	79	22	Peterborough	92	34
Edmonton	76	20	Port Arthur	73	31
Medicine Hat	90	26	Port Burwell	—	—
Minnedosa	82	26	Port Dover	88	37
Moosejaw	92	25	Port Stanley	78	36
Oakbank	79	27	Queensborough	86	29
Portage la Prairie	81	29	Ronville	84	30
Prince Albert	78	28	Southampton	86	38
Qu'Appelle	87	19	Sundridge	—	—
Regina	85	24	Stonecliffe	84	20
Saskatoon	80	26	Stoney Creek	94	37
Souris	81	27	Toronto	95	39
Swift Current	86	24	Uxbridge	90	35
Winnipeg	80	26	Wallaceburg	90	41
Ontario			Welland	86	36
Agincourt	93	36	White River	76	22
Aurora	—	—	*Quebec*		
Bancroft	84	31	Brome	81	27
Barrie	88	37	Father Point	82	31
Beatrice	84	31	Montreal	80	39
Bloomfield	84	38	Quebec	79	32
Brantford	91	37	Sherbrooke	80	31
Chapleau	75	31			
Chatham	—	—	*Maritime Provinces*		
Clinton	89	35	Charlottetown	74	36
Collingwood	96	40	Chatham	78	32
Cottam	90	35	Dalhousie	—	—
Georgetown	90	36	Fredericton	79	32
Goderich	—	—	Halifax	72	36
Gravenhurst	85	38	Moncton	77	32
Grimsby	91	39	St. John	75	40
Guelph	88	28	Sussex	—	—
Haliburton	88	29	Sydney	74	36
Huntsville	85	32	Yarmouth	78	36

EARTHQUAKE RECORDS BY THE MILNE SEISMOGRAPH, TORONTO.

SIR FREDERIC STUPART, DIRECTOR.

P.T. = Preliminary Tremors. S. = Secondary Waves. L.W. = Large Waves. A.C. = Air Currents. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1919	P. T. Comm.	S. Comm.	L.W. Comm.	Max.	End.	Max. Amp.	Remarks
		h m	h m	h m	h m	h m	mm.	
2042	Sept. 1			20?10.2			0.1	Micros going on.
2043	" 6		9?36.0	9 41.1 9 43.6	9 45.0	10 37.9	1.7	
2044	" 13			11 37.2 11 39 6	11 40.5	11 46.5	0.2	Doubtful as to being Seismic.
2045	" 13		12?25.3	12 34.4 12 53.9	12 57.4		0.8	Difficult to read.
2046	" 13			14 21.7 14 37.3	14 37.7		0.2	Doubtful as to being Seismic.
2047	" 15			17 48.8	17 52.5		0.3	Micros going on.
2048	" 19			3?28.7 3 31.4			0.05	
2049	" 22			11 40.1			0.2	Doubtful as to being Seismic.
2050	" 26			9 37.1 9 40.7			0.1	Doubtful as to being Seismic.
2051	" 26			21 07.8 21 10.0	21 11.4		0.3	L. 21 25.6
2052	" 27			3 52.8 3 53.8	3 57.7	4 21.7	0.8	
2053	" 30			7 53.5		8 01.3	0.05	

Period of Boom 18 seconds. Pillar inclination 1 mm = 0".45.

VICTORIA, B.C.

F. NAPIER DENISON, SUPERINTENDENT.

No.	Date 1919	P.T. Comm.	S. Comm.	L.W. Comm.	Max.	End.	Max. Amp.	Remarks.
		h m s	h m s	h m s	h m s	h m s	mm.	
2038	Sept. 1			20 04 46	20 07 13	20 13 07	0.3	
2039	" 6	9 49 48		9 58 10	10 05 04	10 38 59	0.5	
2040	" 13	12 32 30	12 41 21	12 53 39	13 11 22	13 58 34	0.5	
2041	" 15	17 46 20	17 47 19	17 49 08	17 50 46	17 59 38	0.4	Off coast of California
2042	" 19				3 40 11	3 49 02	0.2	
2043	" 22			11?36 32			0.05	Doubtful as to being Seismic.
2044	" 26			20 04 50	20 13 4	22 07 47	0.4	Probably Honolulu.
2045	" 27				4 08 23	4 14 46	0.1	
2046	" 30	7 45 52		7 47 50	7 49 17	7 54 12	0.3	

Period of Boom 18 seconds. Pillar inclination 1 mm = 0."54.

Magnetic Disturbances.

The principal magnetic storms recorded during the month of September at Agincourt and Meanook are as follows:

75th M.T.		Range.			
Beginning	Ending	Agincourt. H	Agincourt. Z	Agincourt. D	Meanook. D
h m	h m	γ	γ	′	′
Sept. 2. 7 22*	Sept. 3. 12 –	125	225	46.7	45.2
" 5. 20 –	" 6. 24 –	357	471	49.6	128.2
" 18. 14 –	" 20. 12 –	515	367	97.8	211.2
" 23. 14 –	" 25. 18 –	196	193	48.7	112.9

*The disturbance of September 2, 3, while only moderate in magnitude was of the sudden commencement type, the time at Agincourt being 7h 22m, whilst at Meanook it was 7h 12m or 10 minutes earlier. Another unusual feature is the smaller range at Meanook than at Agincourt in Declination.

Sun spots were fewer in number than in August, but at no time was the sun free from spots. The maximum spottedness occurred during the last week of the month.

The aurora was most brilliant on the 15th, 18th, and 19th, and was visible in all parts of Canada. Fainter auroræ were recorded generally from the 14th to the 25th, and a very few during the first week of the month.

W. E. W. J.

ACTION OF GRAVITATION ON LIGHT

A Joint Meeting of the Royal Society and the Royal Astronomical Society was held, on November 6, 1919, as a "Meeting for Discussion", the subject being the results of the Observations obtained at the Total Solar Eclipse on May 29, 1919.

The following Summary of the opening Paper was supplied:—

Sir F. W. Dyson, F.R.S., A. S. Eddington, F.R.S., and C. Davidson. A Determination of the Deflection of Light by the Sun's Gravitational Field, from Observations made at the Total Eclipse of the Sun, 1919, May 29.

The paper gives the results obtained in the expeditions to observe the solar eclipse of May 29, sent out by the Joint Permanent Eclipse Committee. Two expeditions were sent out—one to Principe, on the West Coast of Africa, the observers being Prof. Eddington and Mr. Cottingham; the second to Sobral, in North Brazil, the observers being Dr. Crommelin and Mr. Davidson. The observers at Principe had the astrographic object-glass of the Oxford University Observatory, which they used stopped-down to 8 inches as a fixed horizontal telescope, into which the field of stars surrounding the sun was reflected from a 16-inch cœlostat. Similarly, the observers at Sobral employed the astrographic object-glass of the Royal Observatory, also stopped-down to 8 inches, and, in addition, a 4-inch lens of 19-feet focus, belonging to the Royal Irish Academy, supplied with light by an 8-inch cœlostat.

Owing to the exceptional number of bright stars in the neighbourhood of the sun, the conditions of this eclipse were specially favourable for the determination of a possible deflection of light, and the attention of the observers was concentrated on this special problem.

Happily both expeditions were successful. At Principe, in spite of cloudy weather, a few photographs were obtained, from which the deflection of the sun's limb was found to be 1.64″.

At Sobral a series of photographs with the astrographic object-glass, considered unsatisfactory on account of the distortion of the reflecting mirror, gave 0.93″ for the deflection at the sun's limb. A very good series of seven photographs, taken with the 4-inch object-glass, gave for the deflection 1.98″, with a probable error, judged from the accordance of the result of about 6 per cent.

The following table gives the deflections observed, compared with those predicted by Einstein's theory (which gives 1.75″ at the sun's limb):—

	Displacement in R.A.		Displacement in Dec.	
No. of Star.	Observed.	Calculated.	Observed.	Calculated.
	″	″	″	″
11	−.19	−.22	+.16	+.02
5	−.29	−.31	−.46	−.43
4	−.11	−.10	+.83	+.74
3	−.20	−.12	+1.00	+.87
6	−.10	+.04	+.57	+.40
10	−.08	+.09	+.35	+.32
2	+.95	+.85	−.27	−.09

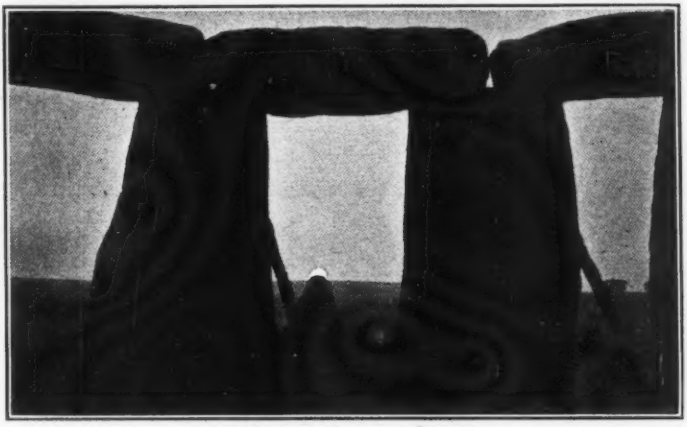
It is concluded that the sun's gravitational field gives the deflection predicted by Einstein's generalized theory of relativity.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

VIEWS OF STONEHENGE

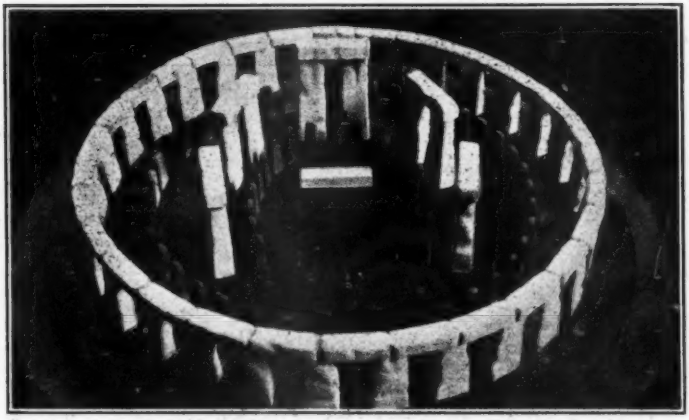
Herewith are reproduced three views of Stonehenge which were furnished by Prof. J. W. Campbell, formerly of Wesley College, Winnipeg, and after the armistice an instructor in the Khaki College. Dr. Campbell is now in the Department of Mathematics and Astronomy in the State University of Iowa. The following notes to the pictures are supplied by him:



3. View of Stonehenge

Herewith are three views of the ancient monument of Stonehenge which is situated on the Salisbury Plain, near Salisbury, in England. In Sir Norman Lockyer's book, *Stonehenge—Astronomically Considered*, a full discussion of the history and astronomical significance of this group of stones is given, and the views here shown may be of interest especially to those who have read Lockyer's book.

No. 1 shows the temple as it probably originally stood in the time of the Druids. It shows the several circles of stones, and within the inner circle in the background is shown the altar stone. No. 2 shows the appearance of the group as it stands to-day. Many of the stones have fallen and one lies broken across the altar stone. The immense size of the stones of which the temple was built is shown by the relative size of a man as seen in this view.



1 AND 2. TWO VIEWS OF STONEHENGE

When one stands on the altar stone and looks across the temple he faces the east, and on the morning of June 21 he sees the sunrise as indicated in No. 3. The stone over which the sun rises on that morning, and which was therefore an index of the summer solstice for the Druids, is about fifty yards from the main group.

It is said that many people gather at Stonehenge every year on the night of June 20 in hopes of seeing with their own eyes the sunrise, as shown, on the following morning, but owing to the nature of the English climate they are not infrequently disappointed.

J. W. C.

An Aurora at a Low Altitude.

Mr. Peter McArthur, the well-known Ekfrid philosopher, in *The Globe* for November 19 described an auroral display which appeared to be near the earth, as follows:

As the hour was late, a waning moon was shining from the east. A cold wintry fog hung over the fields. The Northern Lights were streaming up the sky, but the amazing thing about them was that they appeared to be starting from the tops of the nearby trees. They did not seem to be the width of a farm away from the observers. At times they seemed like strong lights glowing in the fog. Probably the peculiarities of the exhibition were due to the fog, but they seem sufficiently remarkable to be worthy of comment. I wonder if scientific observers have recorded any observations of Northern Lights appearing near at hand.

Some years ago the late Andrew Elvins described to me an aurora which appeared to him to be between his house on St. Vincent Street and the Yonge Street Fire Hall. Reports of other observations of auroras which seemed near the earth's surface have been given in this Journal and in the earlier *Transactions* of the Society.

Observatory Club.

The fortnightly meetings of the Club consisting of the technical members (17) of the staff at the Dominion Observatory, Ottawa, have been resumed for the winter series. The following is the programme of subjects that will be presented and discussed:

(*a*) Earth Tides. (*b*) The Easterly Drift of the Uppermost Atmospheric Layer and Meteors; by Otto Klotz.

The Electric Time Service supplied by the Dominion Government; by W. A. Dier.

The Rôle of Radiation Pressure in Stellar Physics; by F. Henroteau.

The Audion Bulb and Radio Receiving Circuits; by J. P. Henderson.

American Meridian Circles; by C. C. Smith.

The Periodic System of the Elements and some Astronomical Consequences; by Ralph E. DeLury.

Review of Researches on Giant and Dwarf Stars, and their Relation to Stellar Evolution; by R. J. McDiarmid.

Spiral Nebulae and Star Clusters; by D. B. Nugent.
Application of Science in the War; by E. C. Arbogast and W. S. McClenahan.
The Thermo-electric Photometer; by R. M. Motherwell.
The Personal Equation in Longitude Work; by A. H. Swinburn.
Variation of Latitude; by W. C. Jaques.
Seismological Research; by G. W. F. Johnston.
The Secular change in the Magnetic Elements; by C. A. French.
Rates of Chronometers, results from tests in the Observatory temperature vault; by R. M. Stewart.
Comparison of the Rotation in the Northern and Solar Hemispheres; by J. L. O'Connor.

O. K.

SIC ITER AD ASTRA.

By A. V. Franklin.

A city, fair to mortal eyes, 'neath sombre moon is sleeping,
And softly up to scudding clouds her radiant lights are creeping.
High up they climb, in tender gleam, a pallid crown of glory,
To shine upon the city fair as halo'd head of story.

And, softly silhouetted there, in the rich light embrasèd,
I see her yearning spires and heights like ghostly arms upraisèd,—
A fairy city in the night, sweet dream of man's endeavor,
From the dark depths in graceful might to rise aloft for ever.

Yet, though the striving arms uplift, 'tis vain for husk to follow
Up where the cosmic light steals back to sun or star to-morrow.
And so the soul, from Glory far, with richer atom chaining,
Glows for a moment through the whole, and goes;—but dust remaining.

Canada's Place in the Sun.

It has often been remarked that Canada's achievements in the Great War have given her a prominent place in the world, and many of us have entertained the view that the University of Toronto contributed its share in the fight for liberty. From this frame of mind, however, I was rudely shaken when I saw the address on a pamphlet, well-printed in English, which was post-marked at Amsterdam and which appeared to be an effort to show that Germany was not chiefly responsible for the war—a piece of propaganda. The address was: "—— ——, Esq., University of Toronto, England".

C. A. C.